REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Service, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
10-02-2001	FINAL	05-15-1999 to 12-31-2000

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
High Resolution Bathymetry and Backscatter of a High-Frequency Test Area	
	5b. GRANT NUMBER
	N000149810867
	5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)	5d. PROJECT NUMBER
Flood, Roger D.	
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Marine Sciences Research Center State University of New York Stony Brook, NY 11794-5000	

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
Office of Naval Research Processes and Prediction Division, Code 322MG 800 North Quincy Street, Ballston Tower One Arlington, VA 22217-5660	
	11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

20011016 123

13. SUPPLEMENTARY NOTES

14. ABSTRACT High-resolution multibeam bathymetry was collected in the SAX99 study area (18 m deep, offshore western Florida) prior to instrument deployment to ensure that moorings were located within a uniform region. The multibeam data defined a region of similar bottom type on a ridge between two muddy depressions, and the moorings were deployed on the ridge. Analysis of backscatter patterns from the 300 kHz EM3000 multibeam echosounder show that backscatter at 15 to 30 degrees from vertical on the ridge is higher on east-west tracks than on north-south tracks. This is due to the presence of east-west trending wave-generated ripples with amplitudes of about 15 cm and wavelengths of about 75 cm on the ridge, with backscatter being higher when the sound beams are perpendicular to the ripples. The backscatter patterns on multibeam records may thus be used for determining the presence and orientation of small-scale topographic relief.

15. SUBJECT TERMS

multibeam, bathymetry, backscatter, sediment processes, shallow water, DRI, SAX99, wave ripples

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Roger D. Flood
U	U	U	UU	6	19b. TELEPONE NUMBER (Include area code) 631-632-6971

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI-Std Z39-18

FINAL REPORT

High Resolution Bathymetry and Backscatter of a High-Frequency Test Area

Roger D. Flood
Marine Sciences Research Center
State University of New York
Stony Brook, NY 11794-5000
phone: (631) 632-6971   fax: (631) 632-8820   email: roger.flood@sunysb.edu
Award Number: N000149810867

LONG-TERM GOALS

Our long-term goal is to understand the processes which create and modify the sea bed and the acoustic properties of the bed in the coastal zone and to understand how seabed morphology and acoustical properties can be studied using high-resolution swath mapping techniques (bathymetry and backscatter).

SCIENTIFIC OBJECTIVES

We used SUNY Stony Brook's EM 3000 multibeam echosounder, a research-grade shallow-water multibeam echosounder operating at 300 kHz, to produce a high-resolution map of the sea bed bathymetry and backscatter in the High Frequency Sound Interaction in Ocean Sediments DRI (SAX99) study area. The prime study area is about 600 m by 600 m at a water depth of 18 m. We collected highly overlapping data to characterize bottom topography, bottom roughness and backscatter patterns immediately prior to the emplacement of bottom equipment and provided information crucial to the deployment of instruments during the experiment. Subsequent analysis has concentrated on better quantifying local variations in backscatter and topography.

APPROACH

For this project, the MSRC/SUNY EM 3000 system was installed on the Research Vessel R/V Tommy Munro (University of Southern Mississippi) with the transducer mounted on a pole attached to the side of the vessel. The EM 3000 system includes the Simrad EM 3000 (echo sounder transducer, surface electronics, logging computer), a TSS POS/MV (ship attitude and DGPS navigation), and a CTD (for determining the sound velocity profile during the survey). Additional components include backup computers for near real-time data reduction, a printer for data display, and a CD-ROM writer for data distribution. We also deployed a bottom-mounted pressure gauge for measuring water surface elevation (tide) changes during the survey. Preliminary data products were provided to other investigators on CD-ROM by the end of the cruise.

The EM 3000 collects bathymetric and backscatter data across a swath that is about four times the water depth. We had a minimum track spacing of 9 to 18 m (0.5 to 1 times water depth) at several different orientations, and our navigational accuracy was about 1 m. This track spacing will allow a final gridding interval of about 1 m for backscatter and bathymetry and for backscatter to be measured at several different incident angles. While navigational accuracy limits gridding to about 1 m, the image data (the higher-resolution backscatter time series) can detect individual oscillation ripples when

the ripples are parallel to the ship track. Thus the resolution of the backscatter data is higher than the 1 m gridding interval.

WORK COMPLETED

Our EM 3000 survey, conducted between September 27 and 30, 1999, covered an area of about 2.5 square kilometers centered around the SAX99 site. We ran survey lines in north-south, east-west, northeast-southwest, and southeast-northwest directions to understand how backscatter changes with orientation. Additional data was collected at other orientations. A pressure gauge provided surface elevation data at the study site. Dr. Robert Stoll (LDEO) joined us for about 1 day and we deployed his bottom sled and free-fall penetrometer within the SAX99 area. We also collected three sediment samples to help understand the observed backscatter patterns. Survey data from the initial north-south and east-west surveys was reduced on board to produce maps of bathymetry, sun-illuminated bathymetry, and backscatter. These maps were given to Dr. Eric Thorsos and others planning SAX99 immediately at the end of the survey in order to assist in determining the mooring locations.

We (including Dr. Larry Mayer and colleagues at UNH) have developed a suite of analytical approaches to take advantage of the phenomenal density of data and to explore approaches to the statistical characterization of the seafloor in terms of both bathymetry and backscatter.

RESULTS

Our results show that the sea bed here is made up of a number of shallower regions (with water depth about 18.5 m) separated by 1 to 2 m deep troughs, spaced about 1 km apart, trending generally downslope (Figure 1). The shallower regions generally dip slightly towards the southeast, and the eastern sides of the troughs are generally slightly steeper than their western sides. Some troughs do not go very far in the onshore-offshore direction, while others cross the survey area. The troughs that have limited onshore-offshore extent form closed topographic depressions. The floors of the troughs tend to be flat and between 50 and 100 m wide. In almost all cases, the trough floors have lower backscatter than do the ridges. The walls of the troughs also tend to have slightly lower backscatter values. We collected grab samples from the high-backscatter ridge (medium sand), from the low backscatter trough (sandy silty mud), and from a closed depression at the eastern edge of our study area where the backscatter was very low (mud). Thus in this area lower backscatter appears to correlate with increased mud content. When viewed at full resolution our data do image the wave oscillation ripples reported by others from the SAX99 study area. The proposed position for one of the acoustic tower moorings was on the eastern flank of the channel. Based on our survey data, the mooring site was moved into the more uniform region between the 18 and 18.5 m contours.

**Sun-Illuminated Bathymetry**   **Backscatter Mosaic**

Figure 1: Bathymetry of the SAX99 study region (0.5 m contours) showing the positions of bottom moorings. The primary instrumented moorings are on the broad high where water depth is between 18 and 18.5 m. Left: sun-illuminated bathymetry. Right: backscatter (higher backscatter is lighter gray shade).
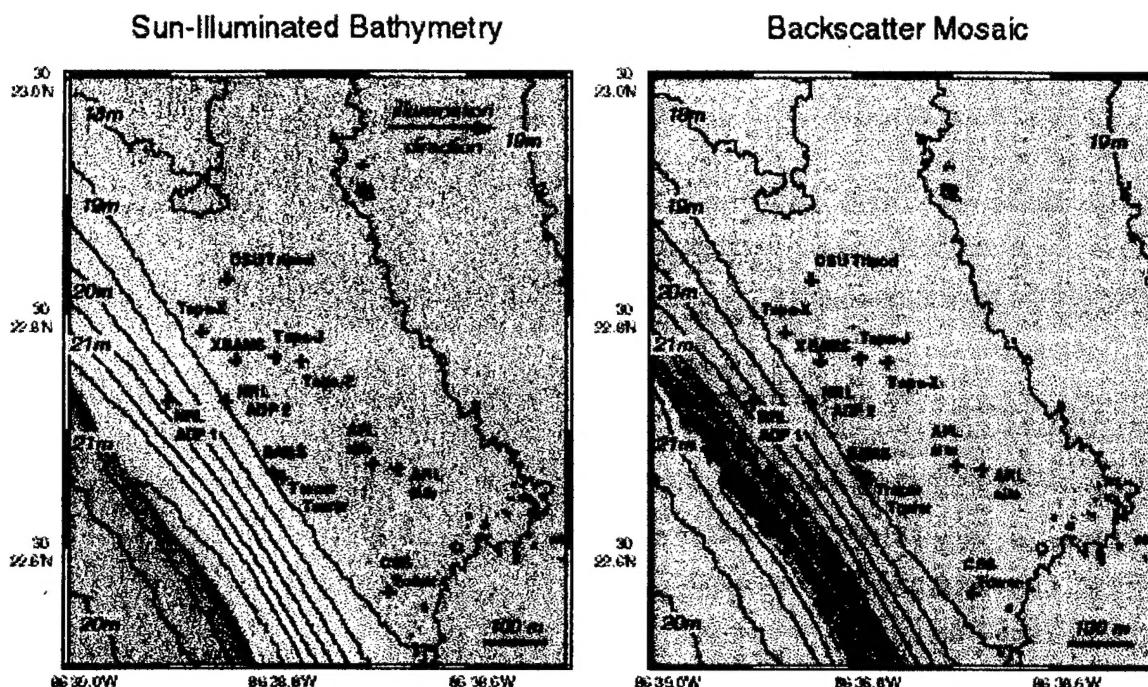
Analysis of multibeam backscatter vs. angle, Figure 2, show that there are distinct regional variations in backscatter patterns. The angular backscatter data from the EM 3000 provides important information about the variability of sediment acoustic properties within the study area, including at the sites of detailed bottom studies. For example, the upper row of Figure 2, collected near the BAMS tower, shows that the character of the backscatter vs. angle plot is different at angles of +/- 15-30 degrees if the sound if travelling perpendicular to the ripples or parallel to the ripples. The stronger backscatter at +/- 15-30 degrees perpendicular to the ripples is most likely due to the topography of the ripple. A distinctly different backscatter pattern is seen in the fine-grained channel (Figure 2, lower left), with lower backscatter at nearly all grazing angles. The lower right plot shows how backscatter varies along a track that extends from the region of the towers towards the channel. A number of different backscatter patterns are intermediate between the other three patterns shown. A next step in our study to characterize backscatter response at the different experiment sites and within the study area as a whole, and we will continue to work with other investigators to understand the causes of the observed backscatter patterns.
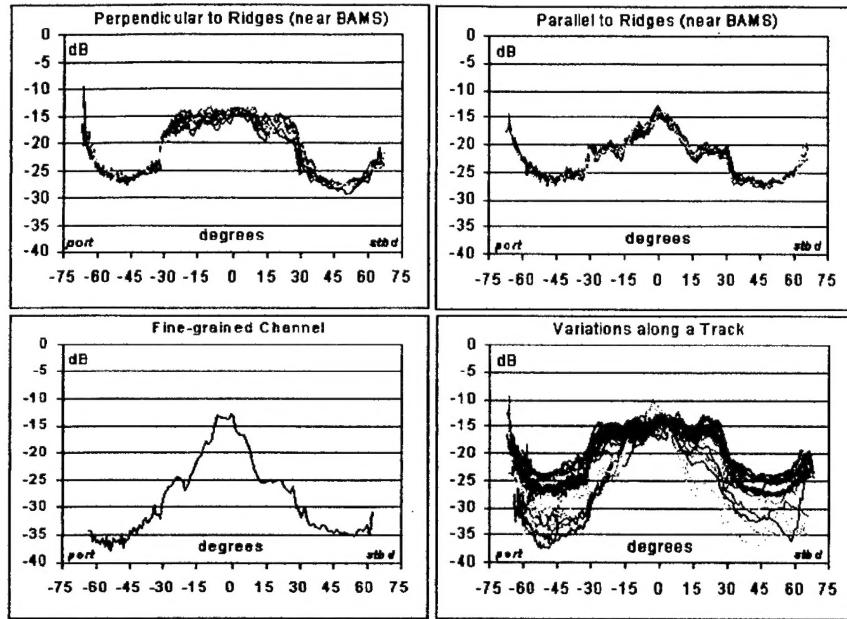
Figure 2: Plots of backscatter vs. beam angle in the vicinity of the BAMS mooring (upper), in the fine-grained channel (lower left), and along a ship track that passes from near the BAMS site into the channel (lower right). The distinct upturn at angles greater than 50 degrees appears to be an instrumenal artifact. Some of the irregularity in the backscatter curves is caused by beam pattern variations.

We have also taken advantage of the remarkable data density in the area (Fig 3a) to develop automated tools for data cleaning and to begin to understand the statistical constraints on automated cleaning tools. A total of 307 lines were gathered in several directions with an average line offset of 10m in a central area of 600x600m, resulting in an average density of 125 soundings/m^2. The massive redundancy provides for robust analysis of the data and allows for error analysis, extraction of a statistically realistic representation of the bathymetry, and thus true radiometric correction of backscattered values (Fig 3b). This geometry also allows us to evaluate mean backscatter as a function of grazing angle for any given piece of seafloor, thus obviating the need to assume a homogeneous seafloor across the swath. These preliminary analyses allow us to approach the problem of remote seafloor segmentation and characterization using the dependence of backscatter on grazing angle with more confidence (Calder et al., 2000). We have also taken the statistical characterization of the processed backscatter values and applied a segmentation algorithm to it. The resulting mapping clearly identifies areas of differing seafloor type (Fig. 4). Ground truth samples have been collected from these regions and will be analyzed.
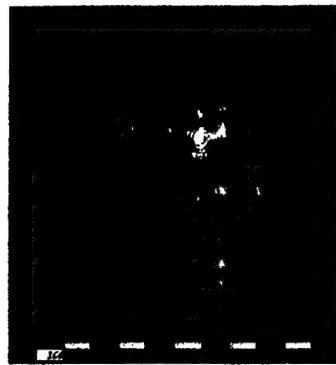
Fig 3a.   Fig. 3b.

Figure 3: a) Multibeam data density per 2 m pixel in SAX99 test area. Red = 700-1000 soundings, yellow = 500 – 700, green = 300 – 500, blue = 0 – 300. b) Cleaned median binned bathymetric surface produced with no manual editing of data in 5 minutes of processing time (Figure from L. Mayer, UNH).
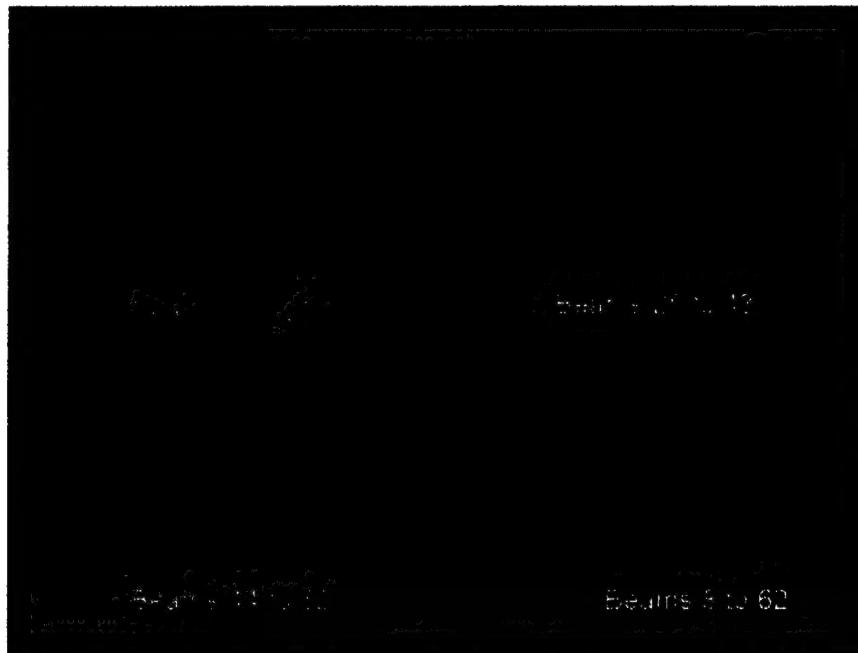
Fig. 4. Color-coded representation of segmentation of backscatter amplitude statistics data for both subsets of beams and nearly all beams. Segmentation consistently defines three sedimentary regimes (Figure from L. Mayer, UNH).

IMPACT/APPLICATIONS

The ability to rapidly and statistically robustly clean multibeam data will have important ramifications on all aspects of seafloor surveying. It is also the starting point of efforts to remotely characterization of the seafloor, a long-sort goal of many communities.

TRANSITIONS

NAVO has been using the SAX99 survey area as a testing ground for their new HSL survey launches equipped with EM 3000 multibeam echosounders. The area was selected as a result of thus study, and we have exchanged survey data thus effectively enhancing the size of our study area.

RELATED PROJECTS

This is a cooperative effort between MSRC/SUNY (Flood) and the Center for Coastal and Ocean Mapping (Mayer). MSRC (with assistance from Dale Chayes at LDEO) built the transducer mounting and installed the equipment on the vessel, and MSRC operated the system during the survey. The SUNY EM 3000 is being used in other programs to characterize shallow-water processes, including the west-coast STRATAFORM area, and insights gained from this study will be applied in these other studies.

REFERENCES

Calder, B.R., Rzhanov, Y., Fonseca, L., Mayer, L.A. and Flood, R, 2000. Statistical Processing of Multibeam Sonar Data from SAX-99 (abs). AGU Fall Meeting, Abstracts and Programs, San Francisco, CA.

Flood, R.D., V.L. Ferrini, and L. Mayer, 2000. Multibeam Bathymetry and Backscatter at 300 kHz in the SAX99 Study Area, West Florida Shelf (abs). AGU Fall Meeting, Abstracts and Programs, San Francisco, CA.

PUBLICATIONS

Richardson, M.D., Briggs, K.B., et al. (including Flood, R.D.), 2001. Overview of SAX99: Environmental considerations. IEEE Journal of Oceanic Engineering, 36: 26-53.